Species	Chen *et al.* (2009)	ZCG (2010)	Bao *et al.* (2012)*	This study Summer (July) ZNWP	This study Early winter (October–November) ZWNP	Gaotai	Dahuwan	Xiaohaizi	Total no. early winter
Common Tern *Sterna hirunda*	x	x	x	200					0
Little Tern *Sterna albifrans*		x							
Whiskered Tern *Chlidanias hybridus*		x	x	2					0
Little Grebe *Tachybaptus ruficallis*	x	x	x	16	6	8	20	2	36
Great Crested Grebe *Padiceps cristatus*	x	x	x	6	1	3	12	3	19
Great Cormorant *Phalacracarax carba*	x	x	x (Xi-60)		1	7	200	5	213
Grey Heron *Ardea cinerea*	x	x	x	1	3	12	18	1	34
Great Egret *Casmeradius albus*	x	x	x		9	93	168	24	294
Chinese Pond Heron *Ardeala bacchus*	x	x	x	1	2		2		4
Black-crowned Night Heron *Nycticarax nycticarax*		x	x	11					0
Yellow Bittern *Ixabrychus sinensis*	x	x	x	6					0
Black Bittern *Dupetar flavicallis*		x							
Great Bittern *Bataurus stellaris*	x								
Eurasian Spoonbill *Platalea leucaradia*		x	x (Xy-16)				51		51
Black Stork *Cicania nigra*	x	x	x (Xy-81)			53	1		54
Total				322	325	3,219	2,269	2,691	**8,504**

[1]Listed as '*C. bewickii*', [2]as '*Anthrapaides virga*', and [3]as '*P. dominica*'. [ ] = provisionally identified. *5pecies records are from Bao *et al.* (2012) and count data is from Bao Xin-Kang (*in litt.* 2012): their counts were made over 24–27 September 2008 except for Whooper 5wan (12 December 2008) and Black-tailed Godwit (6 August 2008). Their survey sites were: 'Da' (Dahuwan), 'Ma' (Maweihu reservoir), 'Mi' (Mingtanghu reservoir), 'Ti' (desert near Tianchenhu reservoir), 'Xi' (Xiaohaizi), 'Xw' (Xiwan), 'Xy' (Xiyaodun); all sites are within the 'Gaotai' area of the current study.

Breeding biology of the Small Snowfinch *Pyrgilauda davidiana* on the Tibetan plateau

SHAOBIN LI, WEIJUN PENG, CHENG GUO & XIN LU

Introduction

The snowfinch complex, *Montifringilla*, *Onychostruthus* and *Pyrgilauda*, comprising eight species, has its central distribution on the Tibetan plateau (Qu *et al.* 2006, Summers-Smith 2009). Occurring from 2,000 to 5,500 m, snowfinches have the highest distributional elevation of all the passerines (Qu *et al.* 2002). They are well adapted to the open alpine meadow and rocky habitats of the Tibetan plateau. Adaptive radiation of snowfinches is thought to have occurred 2 million years ago with dramatic climatic changes caused by the uplift of the Tibetan plateau (Qu *et al.* 2006). However, data on the basic natural history of these species are sparse, although breeding of White-winged Snowfinches *Montifringilla nivalis*, White-rumped Snowfinches *Onychostruthus taczanowskii* and Rufous-necked Snowfinches *Pyrgilauda ruficollis* has been briefly described (Cramp & Perrins 1994, Zeng & Lu 2009a,b).

The Small Snowfinch *P. davidiana* weighing about 20 g, is one of the smallest snowfinches (Clement *et al.* 1993), distinguished from other snowfinch species by a black face mask continuous with a prominent black patch on the throat. It is found in the Russian Altai, Transbaikalia, Mongolia and north China, inhabiting meadow and semi-desert areas, mostly between 1,000 and 3,500 m. Little is known about the reproduction of this species. Here, we report the breeding biology of the Small Snowfinch at an altitude of 3,400 m on the north-east Tibetan plateau.

Study site and field procedure

This work was conducted during 2010–2011 in Tianjun county, north-east Tibetan plateau (37.283°N 99.017°E) at 3,400 m. The annual mean temperature in this area is −1.1°C and the total precipitation 345 mm (data from the weather records of a local weather station from 1990 to 2010). This site is an open, flat meadow landscape. More information on vegetation and other aspects is available in Wang *et al.* (2007) and Li & Lu (2012a).

We searched for snowfinch nests within a 180 ha study plot by following adults' breeding activities. The nests were located in abandoned burrows of Black-lipped Pikas *Ochotona curziona*. When a nest was discovered, we mapped the location with a GPS and recorded the direction of the burrow entrance. Adults were caught by mist-net at the burrow entrance during the nestling period, and ringed with colour rings and a numbered metal ring. We measured their body weight and the length of body, wing, tarsus and bill using an electronic balance and calipers. The sexes are similar, and adults were sexed by social behaviour, a female-specific incubation patch and the throat-patch (bigger and darker in males than females).

For some nests, we dug vertical inspection holes where the tunnel changed direction to find the nest. The inspection hole close to the nest was packed with soil-filled bags to facilitate subsequent inspections, and other holes were covered with original greensward to reduce the risk of predation. Egg size, clutch size, incubation period, nestling period and fledging success were estimated through checking nest contents. Hatchlings were marked by clipping specific tufts before they were eight days old; later they were ringed following the same procedure as for adults. Young from selected nests were weighed every three days. Nests were visited at least once a week to check nestling development and the current condition of the nest. When dates of egg laying, hatching or fledging were approaching, we increased nest visits to record these events as they occurred. Nest dimensions were measured after the young fledged. Nesting activities (nest building, copulation, incubation, brooding, provisioning and sibling competition behaviour) were recorded for selected nests. Parents delivering food almost invariably landed 20 cm or more from the entrance before coming in. This behaviour allowed us to identify the feeder's sex and nestling diet by direct observations at a distance of 20 m from the nests.

Data analysis

In total, 29 nests were located during the two breeding seasons. The date of laying the first egg was determined either by direct observations or by back-dating from the mean nesting parameters of the closely monitored nests. It was assumed that incubation had started if a female regularly stayed in a burrow for more than five minutes. A nest with one or more fledglings was considered successful. We pooled the data from the two seasons for analysis because of the small sample size in each year.

Chi-square tests were used to determine whether the direction of burrow entrances deviated from a random distribution. Independent- or paired-samples *t* tests were used to compare the means of two variables. The growth rate of nestling weight was fitted to a logistic curve. All the analyses were performed in SPSS (v 16). Statistical significance was set as $P < 0.05$ and values were expressed as mean±SD.

Results

Sexual dimorphism

Adult males were larger than females. Significant differences between the sexes were found in body weight, body length and wing length, while tarsus length and bill length were similar (Table 1).

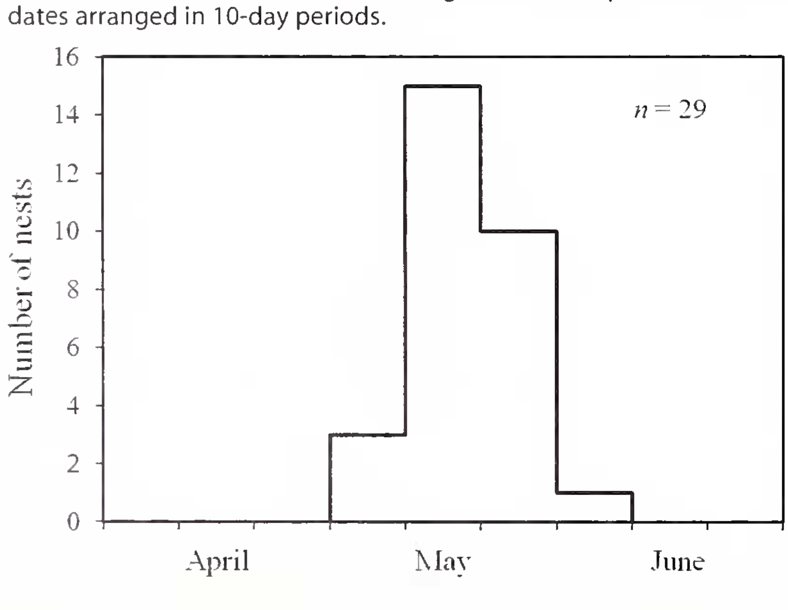
Table 1. Adult biometrics of the Small Snowfinch.

	Male (n = 12)		Female (n = 12)			
Body parameters	**Mean±SD**	**Range**	**Mean±SD**	**Range**	***t***	***P***
Body weight (g)	22.3±1.2	19.7–24.5	19.9±1.3	17.8–21.9	4.78	< 0.001
Body length (mm)	120.7±3.9	117–130	114.6±3.4	109–121	3.78	0.001
Wing length (mm)	86.4±1.1	84.9–88.5	83.0±2.0	80.1–86.1	5.13	< 0.001
Tarsus length (mm)	21.3±0.8	20.4–22.5	21.1±0.6	19.9–21.8	0.94	0.36
Bill length (mm)	10.2±0.3	9.5–10.7	10.3±0.3	9.5–10.7	0.18	0.86

Breeding season

This species is socially monogamous (based on observations of 12 marked pairs). Breeding density was 0.13 pair per ha. Eggs were laid from early May to early June with a peak in mid-May (Figure 1).

Figure 1. Distribution of first egg dates for the Small Snowfinch. The data from the 2010 and 2011 breeding seasons are pooled and the dates arranged in 10-day periods.



No second nesting attempt was observed (n = 12 marked pairs). After the young fledged, adults foraged with their offspring and no further breeding was attempted.

Nest

Nests were in the chambers or at the end of a tunnel branch of pika burrows, 118±50 cm (range: 78–234 cm, n = 8) from burrow entrances. The directions of nest entrances did not deviate from a random distribution ($\chi^2 = 5.3$, $df = 3$, $P = 0.15$). The number of pika burrows within a 36 m^2 radius around snowfinch nests was 2.7±1.0 (1–5, n = 29), which is significantly lower than that of randomly selected burrows (6.0±2.4, 1–9, $n = 26$; $t = 8.1$, $df = 53$, $P < 0.001$).

Both sexes were involved in the construction of their nest. The nests were bulky, made of grass stems and lined with animal hair, feathers and fibres in the inner cup (Plate 1). Nests weighed 208± 47 g (124–267 g, n = 6 nests), with a mean external diameter of 16± 1.5 cm (13.5–17.8 cm), mean internal diameter of 7±1 cm (5.75–8.3 cm) and mean cup depth of 7.4±2.3 cm (4.5–10 cm). Eggs were white without spots (Plate 1). Mean length and width of 35 eggs was 18.8±0.6 mm (17.9–19.9 mm) and 14.4±0.2 mm (14.2–14.7 mm), respectively. Clutch size averaged 5.8±0.4 eggs (5–6, n = 6), and fresh eggs weighed 2.38±0.15 g (n = 17).

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Plate 1. Adult, nest, eggs and chicks of the Small Snowfinch. May and June 2011.

Parental investment

Incubation was by the female only. The mean incubation period was 11.7±0.8 days (11–13 days, n = 6). Nestlings were brooded by the female alone for 3–5 days after hatching. Both the parents fed the offspring. Observation of nine pairs for 715 minutes showed that the female feeding rate per hour was similar to that of males (5.6±2.9 vs. 5.2±3.4, paired-samples test: $t = 0.39$, $df = 32$, $P = 0.7$). All the food delivered to nestlings were insects, consisting of 43% Diptera, 39% Hymenoptera, 10% Coleoptera and 8% Lepidoptera (n=100 feeding trips to nine nests). Nestlings fledged and left the nest burrow at 19.9±1.1 days (19–22 days, n = 8). The logistic growth equation for body weight of 17 nestlings from five nests was calculated: weight = $16.28/(1+e^{0.88-0.24d})$. Fledglings weighed 15.8±1.7 g (n = 13), 75.6% of the adult average weight. Fledged juveniles were fed by their parents for more than a week (n = 5 nests).

Nestling mortality

Eight broods had an average size of 3.75±0.95 (3–5) before the fifth day after hatching. Less than three days before fledging, brood size declined to 2.88±0.69 (2–4; Wilcoxon test, $z = 2.33$, $P = 0.02$). These nests suffered nestling mortality as the bodies were left in the nesting burrows. We observed the dominant nestling (the biggest in body weight) often sitting near the burrow entrance, waiting for the parents to arrive with food (9/16 cases in five nests). During the early post-fledging period, the young remained in tunnels near the burrow entrance. When parents provisioned, the dominant nestling was often the first one rushing out to beg for food (16/31 cases).

Breeding success

Of 29 known-fate nesting attempts, 86% successfully fledged at least one young. Nesting failure was due to excavating activities of pikas (1), predation by Mountain Weasels *Mustela altaica pallas* (2) or unknowns reasons (1).

Social behaviour

Once a pair formed, the male spent most of his time following his mate. We observed seven copulation attempts by five pairs during the egg-laying period, all of which were initiated by the male. Males fed their mates during the egg-laying and incubating period. Males exhibited territoriality throughout the breeding season, evicting any conspecific invaders and even heterospecifics, such as Oriental Skylarks *Alauda gulgula* and Horned Larks *Eremophila alpestris*, that approached their nest entrance (< 3 m). Both the male and female roosted in nesting burrows; after fledging, the family no longer used the nesting burrow as a roosting site ($n = 9$).

Small groups (5–20 individuals) formed as post-fledging families amalgamated in autumn. During the winter, large groups (more than 100 individuals) foraged on the ground, especially in snowy conditions. These groups often roosted at night in cliff cavities or in abandoned huts.

Discussion

Despite using abandoned pika burrows as nest sites, Small Snowfinches, like Rufous-necked Snowfinches (Lu *et al.* 2009), preferred nesting in areas where pika densities were relatively low. This might reduce disturbance due to pikas' excavation activities, which can block the tunnels of snowfinch burrows (Lu *et al.* 2009, Zeng & Lu 2009a,b). In contrast, the White-rumped Snowfinch prefers active pika burrows (Lu *et al.* 2009). This may be because this species is larger—at 40 g, the biggest snowfinch—compared to its two congeners (20 g and 27 g respectively) and more aggressive towards pikas (Lu *et al.* 2009).

The Small Snowfinch laid an average clutch of 5.8 eggs, compared to the 4.7 eggs of the White-rumped Snowfinch (Zeng & Lu 2009b). Snowfinch clutches are larger than those of several sympatric open-nesting passerines, e.g. Oriental Skylark and Horned Lark (2.4–3.2 eggs) (Zeng & Lu 2009b). Both snowfinch species have similar incubation periods (11.7 and 12.7 days) and nestling periods (19.9 and 21.0 days). The former is near to but the latter much longer than local open-nesting species (incubation period 11–12 days, nestling period 9–12 days). Longer duration of nestling growth is characteristic of cavity nesters (Martin & Li 1992), and could improve individual immune function (Ricklefs 1992).

Brood reduction was common in this snowfinch population. It implies insufficient food supply for nestlings in association with low temperature and poor rainfall in the high-altitude region (Mock & Forbes 1994, Parker *et al.* 2002, Roff 2002). However, brood reduction rarely occurs in a sympatric cavity nester, Hume's Groundpecker *Pseudopodoces humilis* (Lu *et al.* 2011). The interspecific difference may be due to different food availability to the two species. Snowfinches feed their nestlings mainly on adult arthropods found in grass, whereas larvae in soil, which are large and nutrition-rich, account for a larger proportion of the diet of groundpecker nestlings. Alternatively the cooperative breeding behaviour of the latter may increase the amount of food delivered to the nestlings. Despite the brood reduction, nesting success of the snowfinches, measured as the percentage of nests from which at least one nestling fledged was 86%, higher than its two congeners (Rufous-necked Snowfinch 56%, White-rumped Snowfinch 67%) (Zeng & Lu 2009a,b), and much higher than most open-nesting species in the study area (< 30%) (Li & Lu 2012b). This could be because nests in cavities suffer from lower nest predation and enjoy better microclimate conditions (Martin & Li 1992).

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